POWER SYSTEM STABILITY ANALYZER

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ABSTRACT

Power systems transient stability phenomena are associated with the operation of synchronous machines in parallel, and become important with longdistance heavy power transmissions. Power system stability may be defined broadly as that property of a power system that enables it to remain in a stable equilibrium state under normal operating conditions and to regain an acceptable equilibrium state after being subjected to a disturbance. In thispaper we proposed different conventional PSSA design techniques along with modernadaptive neuro-fuzzy design techniques. We adapt a linearized single-machine infinite bus model fordesign and simulation of the PSSA and the voltage regulator (AVR). We use 3 different input signalsin the feedback (PSSA) path namely, speed variation(w), Electrical Power (Pe), and integral ofaccelerating power (Pe*w), and review the results in each case.For simulations, we'll use two different linear design techniques, namely, root-locus design, andpole placement design; and the preferred non-linear design technique is the adaptive neuro-fuzzybased controller design.

Keywords:Frequency stability, oscillatory stability, power system stability, terms and definitions, transient stability, voltage stability.

I. INTRODUCTION

Power system stability hasbeenrecognized asan important problemforsecuresystemoperation sincethe1920s[1], [2]. Many major blackouts caused by power system instability have illustrated the importance of this phenomenon [3]. Historically, transient instability has been the dominant stability problem on most systems, and has been the focus of much of the industry's attention concerning system stability. As power systems have evolved through continuing growth in interconnections, use of new technologies and controls, and the increased operation in highly stressed conditions, different forms of system instability have emerged. For example, voltage stability, frequency stability and interarea oscillations have become greater concerns than in the past. This has created a need to review the definition and classification of power system stability. A clear understanding of different types of instability and how they are interrelated is essential for the satisfactory design and operation of power systems. As well, consistent use of terminology is required for developing system design and operating criteria, standard analytical tools, and study procedures.

Our specific focus in this project is of small disturbance stability which is a part of the rotor angle stability. Also, the voltage stability due to small disturbances is covered.

- **Rotor angle stability:**

This refers to the ability of the synchronous generator in an interconnected power system to remain in synchronism after being subjected to disturbances. It depends on the ability of the machine to maintain equilibrium between electromagnetic torque and mechanical torque of each synchronous machine in the system. Instability of this kind occurs in the form of swings of the generator rotor which leads to loss of synchronism.

- **Small Disturbance Stability:**

Small Disturbance stability may refer to small disturbance voltage or rotor angle stability. The disturbances are sufficiently small so as to assume a linearized system model. Small disturbances may be small incremental load changes, small control variations etc. It does not however include disturbances due to faults or short circuits.

II. Excitation system of the synchronous generator

This project to design the power system stability analyzer. The first step in the sophistication of the primitive excitation system was the introduction of the amplifier in the feedback path to amplify the error signal and make the system fast acting. With the increase in size of the units and interconnected systems, more and more complex excitation systems are being developed to make the system as stable as possible. With the advent of solid-state rectifiers, ac exciters are now in common use.

A modern excitation system contains components like automatic voltage regulators (AVR), Power System stability analyzer (PSSA), and filters, which help in stabilizing the system and maintaining almost constant terminal voltage. These components can be analog or digital depending on the complexity and operating conditions. The final aim of the excitation system is to reduce swings due to transient rotor angle instability and to maintain a constant voltage. To do this, it is fed a reference voltage which it has to follow, which is normally a step voltage. The excitation voltage comes from the transmission line itself. The AC voltage is first converted into DC voltage by rectifier units and is fed to the excitation system via its components like the AVR, PSSA etc. the different components are discussed later.

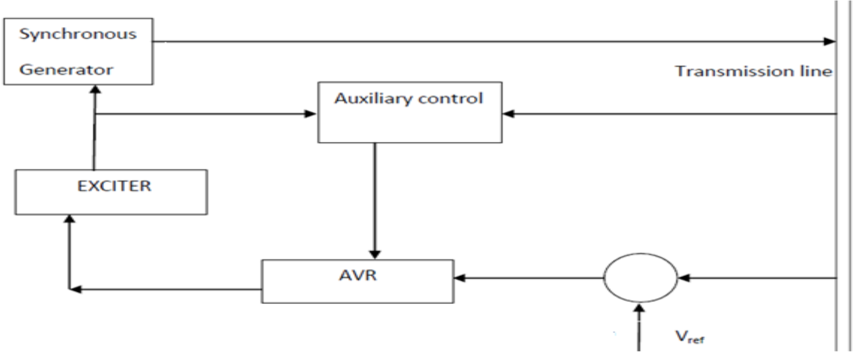

Fig.1. Schematic of the excitation system

III. DESIGN CONSIDERATIONS

Although the main objective of PSSA is to damp out oscillations it can have strong effect on power system transient stability. As PSSA damps oscillations by regulating generator field voltage it results in swing of VAR output. So the PSSA gain is chosen carefully so that the resultant gain margin of Volt/VAR swing should be acceptable. To reduce this swing the time constant of the „Wash-Out Filter ‟can be adjusted to allow the frequency shaping of the input signal. Again a control enhancement may be needed during the loading/un-loading or loss of generation when large fluctuations in the frequency and speed may act through the PSSA and drive the system towards instability. Modified limit logic will allow these limits to be minimized while ensuring the damping action of PSSA for all other system events. Another aspect of PSSA which needs attention is possible interaction with other controls which may be part of the excitation system or external system such as HVDC, SVC, TCSC, FACTS. Apart from the low frequency oscillations the input to PSSA also contains high frequency turbine- generator oscillations which should be taken into account for the PSSA design. So emphasis should be on the study of potential of PSSA-torrsional interaction and verify the conclusion before commission of PSSA.

IV. DESIGN OF AVR AND PSSA USING COVENTIONAL METHODS

In our model for the control of the single-machine excitation system, we have two aspects of design namely:

a) Voltage regulator (AVR) b) Power system stability analyzer (PSSA)

The power system stability analyzer design performed by us has been grouped under two heads:

1. Root-Locus approach (Lead-Lead compensator)
2. State-Space approach (Observer based Controllers)

We have now discuss each method in details; the steps involved, the results obtained and finally, give a brief review on the merits and demerits of each method.

ROOT LOCUS METHOD:

a) **Design of the AVR:** We take a PI controller as the voltage regulator having the transfer function, V(s). The constants Kp and Ki are to be chosen such that the design specs: $t_r < 0.5$ sec and $M_p < 10\%$ are satisfied. For this, we make a table of different Kr and Kp values and their corresponding Tr and Mp valuesWe get Kp=35 and Ki=0.6 which satisfy the above specifications.

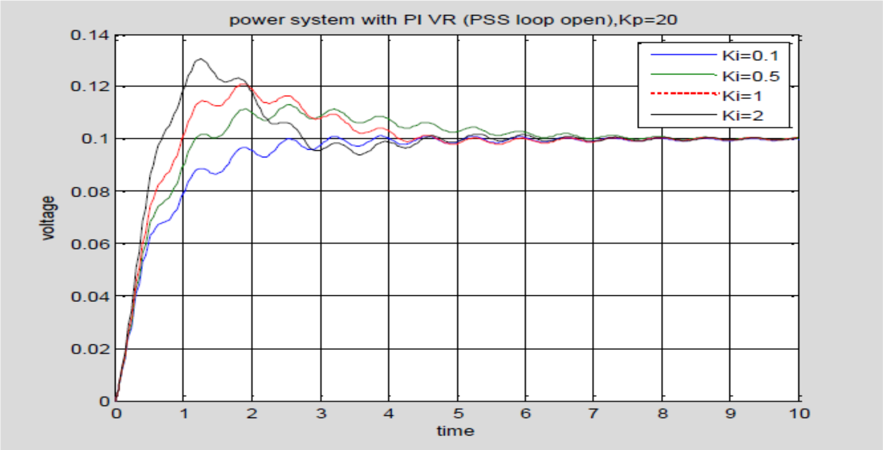

Fig 2:Step response for regulation loop for different Ki values.

b) **Design of PSSA:**We close the VR loop with the above Kp and Ki and simulate the system response for a step input. The above plot shows that the steady state error =0.

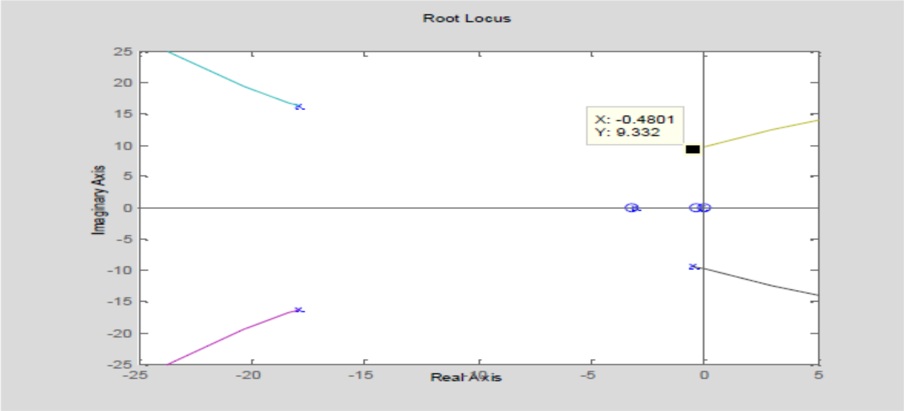

Fig 3: Root locus of PSSA loop showing the dominant complex poles.

Next, we implement this PSSA and close the loop and simulate the response. The root- locus plot of the final PSSA loop and the comparison of responses are given below:

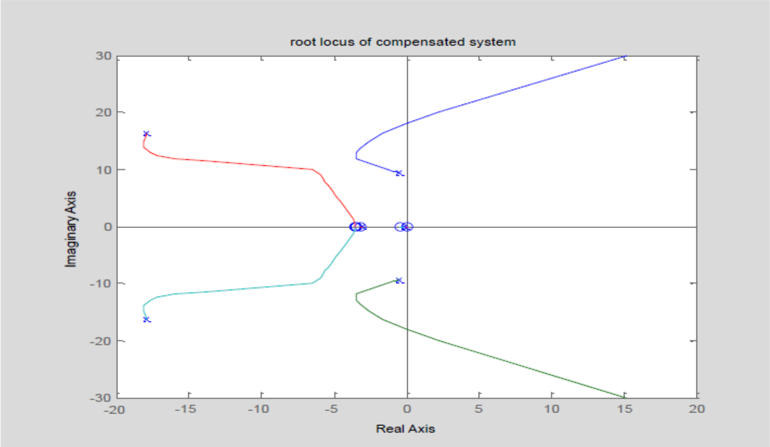

Fig 4: Root-locus of the final PSSA loop showing Φd 180° for dominant poles

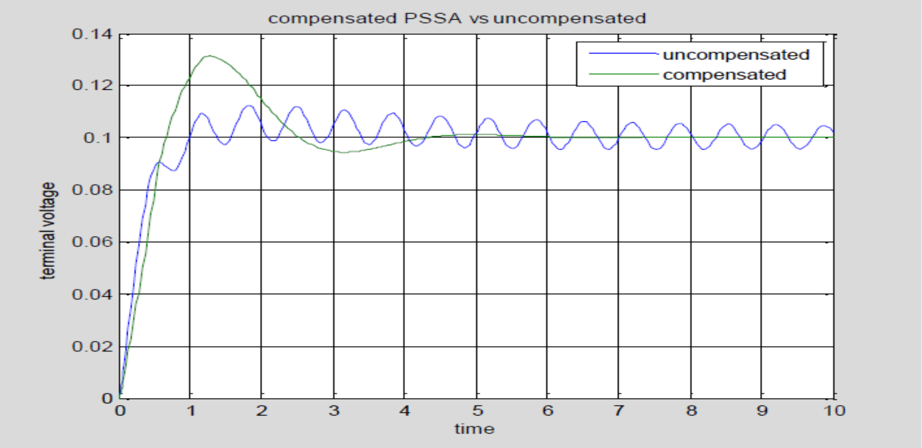

Fig 5: Comparison of step response of uncompensated and compensated systems

V. CONCLUSION

The optimal design of Power System stability analyzer (PSSA) involves a deep understanding of the dynamics of the single machine infinite bus system. In this paper, we have tried to design the PSSA using control system principles and hence view the problem as a feedback control problem. Both conventional control design methods like root-locus method, frequency response method and pole placement method as well as more modern adaptive methods like neural networks and fuzzy logic are used to design the PSSA. By comparison of these methods, it is found that each method has its advantages and disadvantages.

The actual design method should be chosen based on real time application and dynamic performance characteristics. In general, it is found from our simulations that the ANFIS based adaptive PSS provides good performance if the training data and algorithms are selected properly. However, adaptive control involves updating controller parameters in real time using a system identifier which can be complicated and expensive. Hence, the economics of the process is also a constraint.

REFERENCE

1. C. P. Steinmetz, “Power control and stability of electric generating stations,” AIEE Trans., vol. XXXIX, Part II, pp. 1215–1287, July 1920.
2. AIEE Subcommittee on Interconnections and Stability Factors, “First report of power system stability,” AIEE Trans., pp. 51–80, 1926.
3. G. S. Vassell, “Northeast blackout of 1965,” IEEE Power Engineering Review, pp. 4–8, Jan. 1991.
4. P. Kundur, Power System Stability and Control. New York: McGrawHill, 1994.
5. V. I. Vorotnikov, Partial Stability and Control. Cambridge, MA: Birkhauser, 1998.
6. V. V. Rumyantsev and A. S. Osiraner, Stability and Stabilization of Motion With Respect to a Part of the Variables. Moscow, Nauka, Russia, 1987.
7. N. Rouche, P. Habets, and M. Laloy, Stability Theory by Liapunov’s Direct Method. New York: Springer, 1977.
8. CIGRE Task Force 38.01.07 on Power System Oscillations, “Analysis and control of power system oscillations,” CIGRE Technical Brochure, no. 111, Dec. 1996.
9. IEEE PES Working Group on System Oscillations, “Power System Oscillations,” IEEE Special Publication 95-TP-101, 1995.
10. T. Van Cutsem and C. Vournas, Voltage Stability of Electric Power Systems. Norwell, MA: Kluwer, 1998.
11. C. W. Taylor, Power System Voltage Stability. New York: McGrawHill, 1994.
12. IEEE Special Publication 90TH0358-2-PWR, Voltage Stability of Power Systems: Concepts, Analytical Tools, and Industry Experience, 1990.
13. T. Van Cutsem, “Voltage instability: Phenomenon, countermeasures and analysis methods,” Proc. IEEE, vol. 88, pp. 208–227, 2000.
14. D. J. Hill, “Nonlinear dynamic load models with recovery for voltage stability studies,” IEEE Trans. Power Systems, vol. 8, pp. 166–176, Feb. 1993.
15. T. Van Cutsem and R. Mailhot, “Validation of a fast voltage stability analysis method on the Hydro-Quebec System,” IEEE Trans. Power Systems, vol. 12, pp. 282–292, Feb. 1997